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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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STUDY OF TECHNIQUES OF SPRUCE BUDWORM SURVEYS IN THE NORTHERN ROCKY MOUNTAIN REGION

1959

Progress Report

Tom T. Terrell and David G. Fellin, Entomologists

Prepared by the
Forest Insect Laboratory
Missoula, Montana

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Extensive surveys of spruce budworm[1/] infestations in the northern Rocky Mountain region were first made in 1950. In 1950 and for several following seasons survey work was almost entirely confined to aerial observations of foliage damage. In 1955, aerial surveys were supplemented by ground surveys to map the infestation boundaries not visible from the air. By 1955 the budworm had infested large areas of Douglas-fir host to the margin of type in Montana. The need for aerial surveys declined in subsequent years and ground crews provided the information needed. In 1956, ground crews recorded the damage to current growth and to that of the previous year. This comparison attempted to show the trend of budworm infestation in the northern Rocky Mountain region.

These early surveys based on foliar damage had an inherent defect since they recorded past events but furnished no basis for projection into the future. Attempts to relate recent damage to expected insect populations was always questionable. In 1956 and 1957 considerable work was done on surveys of overwintering larvae by Terrell (1). This was the first large scale survey in the region based on budworm population which attempted to forecast populations.

During the past two years the need for biological evaluations that will determine infestation trends has become increasingly obvious. More intensive surveys to obtain data derived from insect populations are essential. In 1959 a survey program designed to provide comparative data on an annual basis was started by establishing a series of permanent sample plots in Montana. The biological evaluation obtained in 1959 from these plots has been presented in a previous report (2).

1/ Choristoneura fumiferana (Clem.)

This progress report contains excerpts from the previous report and presents a detailed description of techniques used to develop methods of improving our biological evaluations. In developing plans for this work we have drawn freely on the experience of the personnel of the Pacific Northwest Forest and Range Experiment Station who have made significant advances in evaluating infestations in their area. Some of their techniques have been altered to fit local conditions where desirable.

There are several ways to evaluate spruce budworm infestations. The method most often used is based on an appraisal of foliar damage caused by larval feeding. While this method is useful and relatively simple to apply, it has a weakness because damage is only the effect of a past generation of insects. The degree of damage is not necessarily a measure of the next generation brood. Survey methods based on abundance of budworm populations are therefore more desirable for a biological evaluation of an outbreak. Because there are several stages of spruce budworm development there are as many periods in which population surveys may be made: egg, hibernating larvae, developing larvae, pupae, and adult moth. Surveys of each developmental stage have both advantages and disadvantages according to the objective in mind. Surveys of budworm egg masses are difficult, time consuming, and expensive, but they offer the advantage of a direct comparison of past and present population through old and current egg masses. Overwintering larvae hibernate on various parts of the host tree. A population survey of hibernating larvae has the advantage of a long dormant period in which to do the work. Such surveys are necessarily made during a difficult time of year for accessibility (midspring) and require the felling of trees for the sample. There are also special problems of transporting the samples and of forcing the larvae to break hibernation. And finally, subsequent sampling must be made on a different set of trees.

Larval development takes place during late spring and early summer. It is a period of rapid change and high budworm mortality--a difficult phase in which to sample large areas. Late in July the surviving remnants of budworm population are in a pupal stage. Moths emerging from the pupae represent a low population point during the budworm's life cycle. The post-pupal period of early August is a very favorable time to survey budworm populations. Empty pupal cases from which moths have emerged are counted in lieu of moths of pupae are collected for moth emergence. A survey of pupal cases is quickly made and final data is almost immediately available. However, there is always danger of a severe storm dislodging pupal cases from the branches before the survey is completed.

OBJECTIVES

The primary objective of the sampling study begun in 1959 is to develop a survey design for predicting the trend of spruce budworm outbreaks that will reasonably be accurate, efficient, and economical. A secondary objective will be the annual evaluation of the spruce budworm infestation in the region.

METHODS

Twenty-five permanent sample plots were established at the beginning of the study in 1959 (figure 1). Four different surveys were made on these plots during the season: (1) overwintering larvae, (2) emerged moth, (3) egg mass, and (4) defoliation damage.

Annual surveys of these plots are expected to provide data that will show the trend of the infestation. By repeated examinations of the same plots and by comparing the data collected, an effective and efficient survey design may be developed that could allow interpretations of various population levels.

Each sample plot consists of five or more intermediate Douglas-fir trees located in an even canopied stand. Except for the survey of overwintering larvae, subsequent surveys were made on the same trees. Limbs and twigs are removed in sampling for the various surveys. Eventually new trees will have to be substituted when the midcrown limbs become sparce. Plot trees were marked with painted numerals for identification. Aerosol paint cans holding 16 ounces were found very convenient for making the numbers as well as making identifying marks leading from the road to the plots. Either red or orange were good colors. A single can was sufficient for several plots.

The following procedures were used for different surveys:

Overwintering larvae.--During April 1 to mid-May, six 6- to 8-inch diameter Douglas-fir trees were felled at each plot location. A section about 17 inches long was cut from each tree bole. These billets were cut near midcrown shortly below the junction of smooth and rough bark. At Missoula, Montana the billets were placed in 5-gallon paperboard ice cream cartons as developed by Denton (3) and illustrated by Terrell (1) to force early emergence of the hibernating larvae. Populations of larvae collected from each sample were expressed as larvae per square foot of bark.

On all subsequent surveys five trees were used for a sample plot.

Emerged moths.--During late July and early August a survey was made to determine the population of emerged budworm moths. Four 15-inch twigs were cut from the cardinal sides at lower midcrown from each of 5 trees. Pupal cases from which moths had emerged were counted for each twig. Pupal cases from which parasites had emerged were not included in this count. Pupae, when still present, were collected and held for emergence in plastic boxes. The number of buds per twig were also recorded.

Defoliation.--In September the foliar damage caused by larval feeding was estimated on each of the five plot trees. Each tree was observed through 9 x 35-power binoculars at range close enough to enable viewer to examine individual buds and needles.

A basis of estimation was developed by first measuring the actual defoliation of a typical limb. Limbs were cut from various parts of the crown with pole pruners or by climbing. Approximately 100 new buds were closely examined and tabulated in one of the following percentage categories of defoliation: 0, 12½, 25, 37½, 50, 62½, 75, 87½, and 100. An average was arrived at for the typical limb. The crown area from which the limb was cut was then inspected through binoculars to give the v viewer a mental image of the appearance of that particular degree of defoliation. Usually, there was no attempt to estimate closer than one of these 12½ percentage points except in very light damage. Three men working on the survey spent two days in such training, checking each other and discussing the problem. After repeated trials there was very little difference in the estimates by these individuals. In practice, each crown third was viewed separately, the estimator quickly decided if the degree of defoliation was above or below 50 percent. If below, the next division was above or below 25 percent, if above it would be classed as 37½, if below it would be 12½. When the estimator could not decide, a count usually revealed the percentage to be close to the 50 percent mark or 25 percent mark or one of these major divisions.

Each individual probably used certain devices to aid him in these estimates. The writer found it advantageous to first look for undamaged buds. There appeared to be a relationship between the number of undamaged buds and the percentage of defoliation. A record of a number of spot checks gave a good relationship between undamaged buds and defoliation. These data show, for example, that where half the new growth buds are undamaged, the total current defoliation will be about 25 percent as:

Percentage of:																
Undamaged buds	2	10	17	24	24	28	34	44	45	50	56	58	61	66	75	90	96
Defoliation	85	70	51	41	38	44	35	32	23	24	14	14	15	21	9	5	2

The percent of defoliation for each tree was weighted in two ways: in both, estimates were made separately for the upper, middle, and lower thirds of each crown. In the one method, estimates of defoliation for each third were weighted by the multipliers 1, 3, 5 for upper, middle, and lower thirds respectively to compensate for the greater amount of foliage in the middle and lower thirds. These results were then divided by the sum of the multiplier (9) to obtain the weighted tree defoliation estimate. In the second method, a weight of 1 was always used for the upper third of the crown and estimated weights were used for the middle and lower crowns depending upon how the foliage complement compared with the top third. The results of these multiplications were then divided by the sum of the multipliers whatever they happened to be. A comparison of the results obtained by both these methods showed that nothing is gained by the second method.

Egg mass.--In conjunction with the damage survey, material was collected for egg mass counts. The equivalent of one whole branch from midcrown was collected from each of the five trees by taking half of the foliage from each of two opposite limbs. Foliage surface area was measured by recording the greatest width and the foliated length of each half limb in feet. (The product of these dimensions was later halved and converted to square inches). The foliage was transported to a temporary laboratory at Townsend, Montana, where a crew of 4 women inspected the foliage and collected all needles having foreign substance resembling budworm egg masses. (Details of operation at Townsend are appended to this report). These needles were later sorted by entomologists who picked out the egg mass-bearing needles and separated them into new (1959) and old (1958) categories. Separating new and year-old egg masses was difficult because of inexperience. About 90 percent of these egg masses could be readily separated into new and old: most new masses were well formed and had a pearly luster, old masses were shrunken and chalky. However, some 10 percent of the egg masses were borderline. To aid in identifying those in question, a collection of new egg masses on 1959 foliage was mounted on a card reference. (New-growth needles shrink and curl after removal from the twig and can later be identified). These new egg masses were of various degrees of deterioration, therefore, by comparing doubtful egg masses with the mounted specimens of known age final separations were made. All old egg masses except a very few remnants were considered to have been deposited in 1958. Undoubtedly some pre-1958 egg masses were counted in this category but they compensate to some extent for 1958 masses lost. These data were recorded on the basis of egg masses per 1,000 square inches of foliage.

Subsequent to the establishment of the permanent plots early in the spring, a few plots were relocated. Only egg mass and defoliation data can be compared for all 25 plots.

In addition to the 25 permanent plots, 64 plots of five trees each were taken on which only the defoliation was recorded. Data from these plots are not treated in this report because the plots are not primarily of a permanent nature. However, the plot trees were numbered and mapped; they can later be incorporated into a permanent sampling system when needed.

RESULTS

Table 1 is arranged in the natural sequence of events although the data were not obtained in that order. It shows the relationship of each event to that following: egg masses of 1958 hatch into the overwintering larvae which in turn cause the defoliation. Adult moths developed from the larval brood and deposited the 1959 egg masses.

Table 1.--Spruce budworm survey data from 25 permanent plots with related statistics for five different phases of activity in the order of occurrence

Plot	1 Egg masses per 1000 sq. in. 1958	2 Overwintering larvae per sq. ft. 1959	3 Percentage of defoliation 1959	4 Moths per 15 in. twig 1959	5 Egg masses per 1000 sq. in. 1959
1 Bitterroot	0.58	1.5	8.6	0.00	0.00
2 Rock Creek	9.80	---	44.3	---	10.80
3 Blackfoot	11.44	14.5	42.3	3.20	16.56
4 West Continental	13.40	36.9	43.7	0.40	11.66
5 South Continental	16.12	13.0	62.2	1.40	7.78
6 Pioneer	0.94	1.6	35.2	0.10	0.32
7 Lima	0.50	0.1	13.5	0.05	0.24
8 Ruby	0.98	10.2	11.3	0.25	3.26
9 Madison	17.66	5.9	34.7	0.60	18.46
10 Hebgen	0.00	0.5	0.3	0.00	0.18
11 Centennial	4.74	28.1	54.5	0.90	12.64
12 Tobacco Root	1.34	0.0	1.8	0.00	0.00
13 Lincoln	12.66	101.4	72.7	2.65	21.98
14 Marysville	4.86	12.3	53.3	2.70	35.18
15 Elkhorn	6.30	8.6	50.1	1.15	10.62
16 Big Belt Mtns.	2.04	0.1	4.0	0.50	1.10
17 Deep Creek	20.48	2.2	36.8	1.85	15.66
18 Smith River	14.64	---	84.4	2.70	21.32
19 White Sulphur	6.88	3.7	90.0	3.50	36.58
20 Bridger	12.92	3.0	67.5	0.65	10.36
21 Crazy Mtns.	10.32	35.3	12.9	0.65	3.92
22 Hyalite	3.84	---	30.2	---	3.56
23 Pine Creek	19.16	84.5	92.8	0.55	7.28
24 Mill Creek	7.40	1.8	11.8	0.15	2.32
25 Slough Cr.(YNP)	5.14	55.5	55.0	1.15	4.08
Total	204.14	420.7	1013.9	25.10	255.86
Average	8.16	19.1	40.6	1.09	10.24

The immediate need in analyzing these data is to determine how well these events are related--can an evaluation of one phase be substituted for another? Will data collected in one development stage be as effective as data in another stage? Answers to these questions are expected to improve technique of evaluating spruce budworm outbreaks.

There is a relationship between the various stages given in table 1. In some instances the correlations are good, in other instances only a trend is indicated. Results of these correlations are given in table 2.

Data on overwintering larvae were most difficult to correlate with other data. Difficulty was experienced with temperature stratification in the greenhouse where forced rearing took place. This resulted in a much greater variance in emergence than in previous years. However, there appears to be a good correlation between hibernating larvae and subsequent defoliation. Better correlations could probably be obtained by stratifying the data into several density classes.

Data on spruce budworm egg abundance may be improved by converting the data to eggs per 1,000 square inches rather than egg masses, although such a conversion did not improve the data taken in 1959. The measurements of 10 egg masses at each plot (where available) gave an average length of 6.9 millimeters. A conversion factor of 5.5 eggs per millimeter was used to estimate the eggs per plot. It would seem more realistic to use eggs rather than egg masses, but, a more accurate conversion factor should be developed; short egg masses have fewer eggs per millimeter than long egg masses.

The relationship between old egg masses, defoliation, emerged moths, and new egg masses appears to be good. If these relationships hold through another season, a survey design based on a combination or modification of these factors may be developed that will provide reliable trend data. Such a survey design may use a rather wide sampling of emerged moths and a limited sampling of budworm egg masses.

Examples of straight-line curves fitted by the coefficient-of-correlation method are presented in the appendix.

The relationship between old egg masses and subsequent defoliation (figure 2) and between moths and egg masses (figure 4) offers a possibility of a future close correlation between moths and defoliation.

The apparent 13 percent defoliation with 0 masses (figure 2) and approximately 7 percent defoliation without moths (figure 3) may be due to variance in the data. However, there is a possibility that sawflies, blackheaded budworm, and twig moths may be a factor.

Additional data in 1960 may provide an improvement in survey design.

Table 2.--Results of some correlations of spruce budworm survey factors

	Hibernating larvae	Defoliation	Emerged moths	New egg masses
Old egg masses	Not significant r = +.395 at p=.05, r=.423	Highly significant r = +.673 at p=.01, r=.505	Not significant r = +.367 at p=.05, r=.413	Significant r = +.434 at p=.05, r=.396
Hibernating larvae		Highly significant r = +.542 at p=.01, r=.537	Not significant r = +.228 at p=.05, r=.423	Not significant r = +.158 at p=.05, r=.423
Defoliation			Highly significant r = +.650 at p=.01, r=.526	Highly significant r = +.667 at p=.01, r=.505
Emerged moths				Highly significant r= +.862 at p=.01, r=.526

LITERATURE CITED

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(2) Terrell, Tom T., Robert E. Denton, and David G. Fellin. Biological evaluation of spruce budworm conditions in the northern Rocky Mountain region. Intermountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, Ogden, Utah. 1960.

(3) Denton, Robert E. Studies of methods of improving the accuracy and general efficiency of spruce budworm surveys: 1951 progress report. Forest Insect Laboratory, Coeur d'Alene, Idaho. April 1952. 9 pp. illus. (Processed)

APPENDIX

Detail of procedure of spruce budworm egg mass survey at Townsend, Montana.--A small two-room Government-owned building at the District Ranger's dwelling in Townsend was used as a laboratory for the separation of egg mass-bearing needles. Provision was made for the work to be done outside in clement weather to take advantage of natural light. A large table was set in the yard and covered with woolen blankets. No provision was made to shade the table. (There was no objection to working in the September sun.) For periods of inclement weather a second table was set up inside the building and covered with blankets. Three fluorescent desk lamps were placed above and lengthwise along the table.

Four women were hired (Forestry aids--research, GS-3 grade) and reported for work September 2, 1959. They were trained by and worked under the supervision of a Laboratory staffman. Training of these technicians required two days but during this period some productive work was done. First, the trainees were oriented in the job by telling them what we were doing and what we expected to accomplish. This included a description of budworm life history and the importance of the insect. Egg masses were exhibited and described. The trainees were instructed to detach each needle having egg masses or any foreign substance on it. A half branch of foliage was then placed on the table and the twigs were snipped off with hand pruning shears and cut into 2- to 5-inch sections. One trainee was instructed to examine a twig by grasping it by the ends and slowly rotating it while viewing from the side. Next the trainee held the twig with the long axis perpendicular to his line of sight and again rotated it. The ends were reversed and the process was repeated--three separate examinations were thus made of each twig. The trainee then passed the twig on to the second trainee. The second trainee examined it and passed it on. This was repeated until the foliage from the half branch was examined by each trainee. Five hours were spent in this phase of the training. Each trainee alternated as to position of first, second, third, or fourth examiner. At first egg masses were missed down to the fourth person. This phase of the training was very important and was carried on until the trainer was confident that each trainee could examine the foliage with a minimum of missed egg masses. Close attention and periodic checks by the trainer were a necessary followup which continued for several days.

Throughout the first day and midway through the second day, all needles bearing foreign matter as well as egg mass-bearing needles were collected by the trainees. However, by noon of the second day too much time was being spent picking and packaging needles having pine needle scale. Scale was quite abundant on some foliage. At this point the trainees who now recognized pine needle scale were instructed to discard it, all other needles with foreign material were collected throughout the period.

Each technician was equipped with a pair of hand pruning shears, forceps, hand magnifier (1½ power), petri dish, and a carton for waste.

The following procedure was used in examining the foliage for egg masses:

1. Each half limb sample (which carried a plot, tree, and sample designation) was placed on the work table. The examiners clipped the foliage into short sections, removing all lateral branchlets.

2. The clipped foliage was piled in the center of the work table. Examiners positioned themselves around the table with their equipment and started the needle examination. Examined foliage was discarded into the waste cartons. Needles having egg masses or other objects on them were removed and placed in petri dishes. Each examiner had a share of the inspection of every sample. When all the foliage of the sample had been examined, the needles in the petri dishes were collected and placed in No. 000 gelatin capsules labelled with the plot, tree, and tree side designations. Unhatched egg masses were packaged separately, one to the capsule to prevent webbing of an entire sample collection by the hatching larvae. Several capsules were sometimes necessary to enclose needles from a single sample. All capsules from a single plot were placed in a 1 x 2 x 3 inch pill box labelled with the plot number. The examination of a new sample was never started until the work was finished on the current sample.

Douglas-fir foliage from the sample plots was brought into Townsend in three forms: (1) complete half limbs, (2) foliage from half limbs packed in 5 gallon paperboard ice cream cartons, (3) foliage from half limbs in 18 x 30 inch plastic bags.

Upon arrival in Townsend, complete half limbs were wrapped in a tarpaulin and placed in the shade. The tarpaulin was kept wet to prevent the foliage from drying. Cartons and plastic bags containing foliage were placed in a walk-in cooler at a local creamery where a temperature of about 40°F. was maintained. The foliage samples were removed from storage as needed. No difficulty was experienced from dropping foliage under any of these treatments. For short hauls, the complete half limb proved a good method but for longer distances the cartons or plastic bags require less space and foliage from three plots could be transported in a panel truck.

A production record of foliage examination by the technicians follows:

Date	Man-days	Function	Accomplishment (No. ½-branch samples examined
September			
2	4	Training	3
3	4	Training	9
4 to 24	56	Foliage examination	238
	64		250

This record shows that about 4.25 half limbs were examined per man-day after a two day training period and that some production is accomplished during training. A trainer should stay at hand for the first several days. After the technicians fully understand the work, one of them can be delegated to capsule the needles and take care of some of the details. The supervisor of this phase of the work was able to do some field work during the period of September 14 to 24.

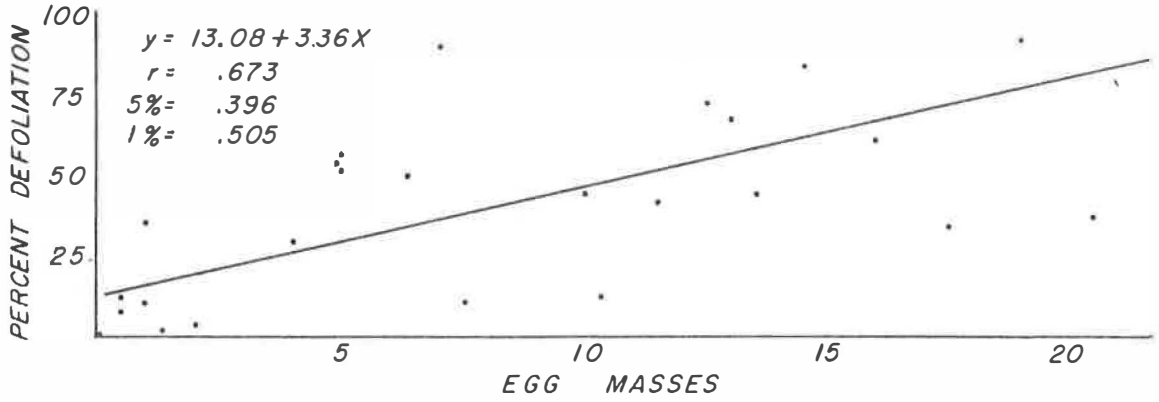

Figure 2.-- Relationship of egg masses per 1,000 sq. in. of foliage in 1958 to percent of defoliation in 1959.

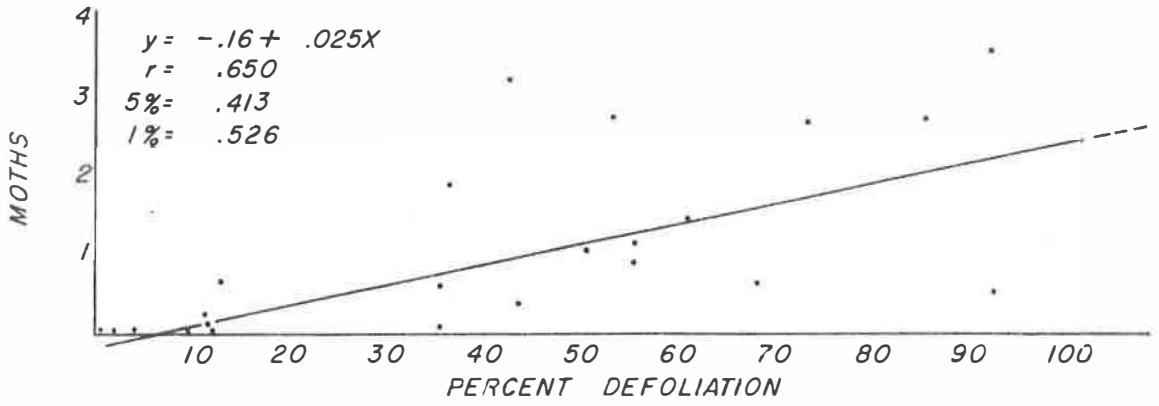

Figure 3.-- Relationship of percent of defoliation to moths per 15-inch twig in 1959

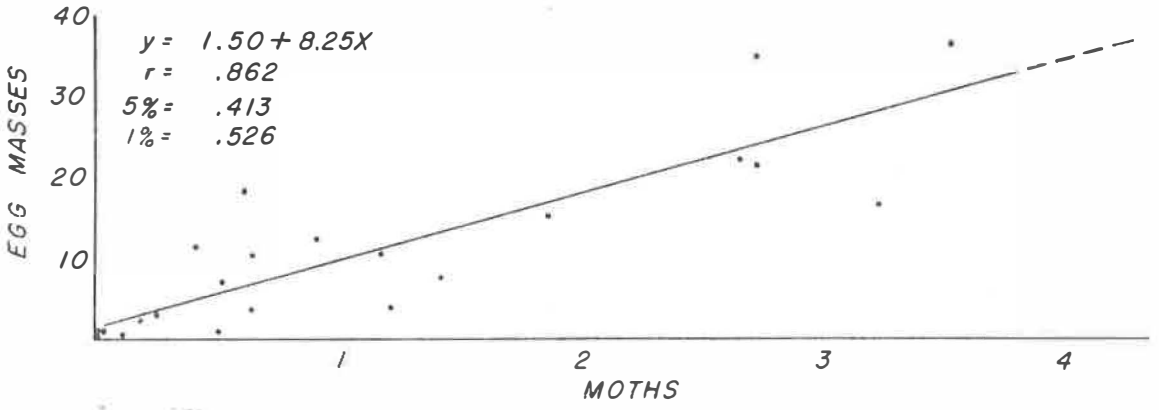

Figure 4.-- Relationship of moths per 15-inch twig to egg masses per 1,000 sq. in. of foliage in 1959